Measurement of Toxic Gas Production During Inhibition of JP-8 Mist Fireball Explosions Aboard an Armored Combat Vehicle via Fourier Transform Infrared Spectroscopy

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Modern ground combat vehicles are equipped with automatic fire suppression systems to extinguish fuel and hydraulic fluid fires. These systems use halogenated hydrocarbons, i.e., Halons, as the fire suppression agent and can suppress fires, even the "Mist Fireball Explosion", in less than 250 milliseconds. Unfortunately, halons have been identified as a major cause of the ozone depletion in the atmosphere and has led to the cessation of the production and sale of Halons[1,2]. Researchers face formidable obstacles in developing suitable replacement agents that equal the fire suppression capabilities of halons. Among the main criteria for the suitability of a Halon alternative are: (1) it must be as effective at extinguishing fires as those agents it replaces, (2) it must be economically viable, (3) its ozone-depletion factor should be lower than 0.2, the level that must be met by the year 2000 under current proposed regulations, (Halons have ozone depletion factors ranging from 3 to 10)[3], and (4) human tolerance for the chemical must be high for the conditions where it is employed.

Recently, this laboratory reported the results of an FT-IR spectroscopic investigation of the toxic gases produced during the inhibition of JP-8 fuel fires by CF_3Br (Halon 1301) and C_3F_7H (FM-200)[4]. It was shown that in JP-8 fires inhibited by either agent, toxic gas products were generated which pose serious health risks to the personnel exposed to the combustion gases. For each agent tested, the principle toxic gases produced during inhibition of JP-8 fires were CF_2O and HF. For JP-8 fires inhibited by CF_3Br, a surprising high level of HBr was also produced.

The current work continues the investigation of the potential toxic decomposition and combustion products formed during the application of fire extinguishing agents within a test fixture constructed from an ex-Bradley Fighting Vehicle hull. A mist fireball explosion is initiated by the detonation of a shaped charge weapon through a sacrificial armor plate mounted on the crew compartment of the vehicle. An aluminum fuel cell filled with JP-8 fuel is mounted just on the other side of the armored plate. The shaped charge jet perforates the plate and the fuel cell, producing pressure waves within the the liquid fuel. Fuel sprays out the cell, producing the fireball.

Infrared spectra of gases removed from the crew compartment of the test fixture were measured using a Midac Corporation Model G-5001-FH Fourier transform spectrometer system operating at 0.5 cm^{-1} resolution. Detection of the infrared radiation was by a liquid nitrogen-cooled Hg-Cd-Te detector. The interior of the spectrometer was purged with dry nitrogen. The spectrometer was ruggedized for outdoor use by the manufacturer. Ruggedization consisted of kinematic mounting of all optical components and the use of ZnSe material for all transmissive optics. The gas samples were removed from the vehicle via a 3/8 inch diameter tube in series with a ten meter path-length multi-pass optical cell and a mechanical

vacuum pump. A two foot length stainless steel sample tube was mounted approximately 12 inches above the sponson and 12 inches from the interior wall in the crew compartment. A portion of the sample tube extending from the exterior wall of the vehicle to the spectrometer was heated to a temperature of 50 °C. The distance between the sampling location and the spectrometer was approximately twelve feet.

After filling the fuel cell with fuel, a single beam background spectrum was collected with the sample valve closed for post-processing of the test spectra. All doors and hatches of the vehicle were closed with the exception of the driver's hatch which was allowed to open and close as a pressure relief. The gas samples were continuously flowed through a ten meter path-length multi-pass optical gas cell (internal volume approx. 2300 cm^3) contained within the FT-IR spectrometer. The multi-pass cell was maintained at a constant temperature of 105 °C.

Prior to the detonation of the shaped charge weapon gas flow from the sampling tube through the spectrometer optical system was begun by opening a valve between a vacuum pump and the exit port of the 10 m path-length optical cell. When gas flow through the spectrometer optical system was established, a series of 320 scans was initiated, with each scan measured at 0.5 cm^{-1} resolution. This gave a temporal resolution of approximately three seconds per spectrum. Approximately 30 seconds after data acaquisition was begun, the shaped charge weapon was detonated. The fire suppression system was deployed 25 milliseconds after the detonation of the weapon.

The agents CF_3Br, C_3F_7H, and C_2F_5H have been tested and results will be reported for each.

References:

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